ANL-6497 ANL-6497

Argonne National Laboratory

SPECIFIC HEAT DATA ANALYSIS PROGRAM FOR THE IBM 704 DIGITAL COMPUTER

by

Pat R. Roach

LEGAL NOTICE

ANL-6497
Chemistry
(TID-4500, 17th Ed.)
AEC Research and
Development Report

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois

SPECIFIC HEAT DATA ANALYSIS PROGRAM FOR THE IBM 704 DIGITAL COMPUTER

by

Pat R. Roach

Solid State Science Division

January 1962

Operated by The University of Chicago
under
Contract W-31-109-eng-38

TABLE OF CONTENTS

FIGURE

SPECIFIC HEAT DATA ANALYSIS PROGRAM FOR THE IBM 704 DIGITAL COMPUTER

by

Pat R. Roach

I. PURPOSE

The purpose of the program described herein is to calculate the specific heat of a substance in the temperature range from 0.3 to 4.2°K, given temperature calibration data for a carbon resistance thermometer, and given experimental temperature drift and heating period data. The specific heats calculated from these data are then fitted by a curve by the method of least squares and the specific heats are corrected for the effect of the curvature of the data.

II. METHOD

The experiment* for which this program was designed is one in which a He^3 cryostat is used in order to achieve temperatures in the neighborhood of 0.3°K by pumping on He^3. The specific heats are determined by applying a measured amount of current to a constantan heater on the sample for an accurately measured length of time. With additional information determined before the experiment for the resistance of the heater, the heat capacity of the empty calorimeter, and the number of moles (or grams) of sample, the specific heat can be determined when the temperature increase due to the heat input is known.

The temperature is determined by measuring the resistance of a carbon thermometer arranged in a four-lead potentiometer circuit. One pair of leads is used to measure the voltage across the thermometer and the other pair carries the thermometer current; this current also flows through a standard resistor, and the voltage developed is measured to determine this current.

Figure 1 shows how this temperature increase is actually determined. Because of unavoidable heat leaks, the temperature of the sample does not remain constant between heating periods, but drifts at a slow rate (assumed to be linear). For this reason, the drifts before and after the heating period are measured as shown in Figure 1. Point C represents the point where heat is turned on, and D represents the point where it is turned off.

---

*Lounasmaa, O. V., and Guenther, R. A., Phys. Rev. 126, May 15, 1962.

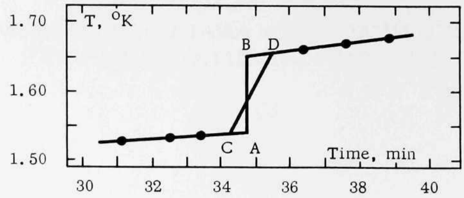

Figure 1

Fore- and after-drifts of a typical heat capacity point

The true temperature increase due to the electrical heating is then found by extrapolating the fore- and after-drifts to the middle of the heating interval, giving points A and B, respectively. The difference in the temperatures of points A and B gives the increase due to the heating, and the mean of these temperatures gives the temperature to which the specific heat is referred.

The carbon thermometer is calibrated against the vapor pressures of He^3 and He^4 by direct vapor pressure measurements where possible and by means of a magnetic thermometer for lower temperatures. Measurements of vapor pressures are done with oil manometers (containing di-n-butyl phthalate) for low pressures and mercury manometers for higher pressures. These readings are then corrected by the program for the relative expansion effects of room temperature on the glass, mercury, and oil, and for the zero corrections of the mercury manometers (see PROGRAM DETAILS). Also included is a correction to standard gravity of 980.665 cm/sec^2, assuming a local value of 980.278 cm/sec^2, and a correction for impurities in the He^3. The latter correction is applicable for small He^4 impurities in the He^3; the correction factor would be 1-x if x were the percent of He^4 in the He^3. The pressures obtained are then referred to He^3* or He^4** vapor pressure tables to obtain values of absolute temperature.

For temperatures too low to yield vapor pressure readings, a magnetic thermometer calibrated at higher temperatures is used. From measurements of the mutual inductance of the magnetic thermometer along with values of temperature determined from vapor pressure readings, a formula is determined for the points of the form

---

*Sydoriak, S. G., and Roberts, T. R., Phys. Rev. 106, 175 (1957) (temperatures converted from T_{55} to T_{58}).

**Van Dijk, H., Durieux, M., Clement, J. R., and Logan, J. K., J. Res. Nat. Bur. Stand. 64A, No. 1, (1960).

$$\kappa = A + \frac{B}{T + (\alpha/T) + \beta} \quad , \tag{1}$$

where κ is the mutual inductance of the magnetic thermometer, T is the absolute temperature, A and B are the parameters to be determined (by the method of least squares), α is an input constant, and β is a constant chosen by the program to give the best fit to the experimental points.

When the constants A and B have been determined, the above formula is inverted and then extrapolated to determine values of temperature corresponding to values of κ in the region too low for helium vapor pressure readings.

The result of the previous calculations is to provide a value of absolute temperature for each value of resistance of the carbon thermometer. The next step is to fit a formula to these data by the method of least squares. For this purpose there are available in the program 33 functions of R, any combination of which can be used to comprise the calibration formula. The final result of this analysis is then a formula

$$\frac{1}{T} = Af_1(R) + Bf_2(R) + \cdots + Nf_n(R) \quad , \tag{2}$$

where A, B, $\cdots$, N have been determined from the calibration points R_1, T_1, $\cdots$, R_m, T_m by the method of least squares.

As the final step in the analysis, a formula whose form can be any polynomial in powers of T is fitted to the specific heat data by the method of least squares. At the same time, the data are corrected for the effect of curvature of the specific heat function. This is necessary because of the finite intervals of temperature used in the measurements and the fact that over such an interval the specific heat function is perhaps not sufficiently linear to yield a completely accurate answer without correction. The least-squares analysis includes the provision for fitting the specific heat data with any combination of terms whose coefficients are floating and free to be determined by the method of least squares, and terms whose coefficients are fixed and entered as input to the program.

III. OPERATION

A. Specific Heat Calculation Program

1. Input

a. Calibration Data. Title Card. The first card to be read by the machine is a title card. The information on this card will be duplicated in all the data output of the same experiment. The first 72 spaces of the card are available for information.

Constants Card. The second card read in by the machine is a constants card containing information necessary for the calibration calculations. It contains the following data:

Word 1: (col. 8-9)	Number of calibration points.
Word 2: (col. 10-20)	Constant α for the magnetic thermometer formula [formula (1)].
Word 3: (col. 21-31)	Zero correction for He^3 mercury manometer in mm of mercury.
Word 4: (col. 32-42)	Zero correction for He^4 mercury manometer in mm of mercury.
Word 5: (col. 43-52)	Purity correction for He^3 manometer readings (e.g., 0.994 if there were 0.6% He^4 in the He^3).
Word 6: (col. 53-62)	Value of standard resistor used to measure carbon thermometer current, in ohms.

Calibration Data Cards. The next cards read in by the machine are the calibration data cards; these contain data as follows:

Word 1: (col. 1-9)	Lower helium vapor pressure manometer reading in mm of oil or mercury.
Word 2: (col. 10-20)	Higher helium vapor pressure manometer reading in mm of oil or mercury.
Word 3: (col. 21-31)	Mutual inductance bridge reading (if any) for magnetic thermometer.
Word 4: (col. 32-42)	Voltage reading of current in carbon thermometer.
Word 5: (col. 43-52)	Voltage reading of carbon thermometer.
Word 6: (col. 53-62)	Reading of room temperature in °C.
Word 7: (col. 65)	Code number from 1 to 5 identifying nature of calibration data. 1 = He^3 oil; 2 = He^3 mercury; 3 = He^4 oil; 4 = He^4 mercury; 5 = no manometer reading.

Word 8: (col. 68-72) Code word as follows:
Col. 68: Experiment number.
Col. 69: Run number (zero if calibration data).
Col. 70-72: Calibration point number.

Calibration Formula Card. The last card comprising the calibration input contains the data for the calibration formula [formula (2)] as follows:

Word 1: (col. 9) Number n of functions to be used for calibration formula.

Words 2, 3, 4, 5, 6, 7, 8, and 9 are in columns 15-16, 19-20, 26-27, 30-31, 36-37, 41-42, 46-47, and 51-52, respectively, and contain the code numbers of the functions to be used for the calibration curve as follows (as many words as necessary, up to 8):

1: $1/R^5$	2: $1/R^4$	3: $1/R^3$
4: $1/R^{5/2}$	5: $1/R^2$	6: $1/R^{3/2}$
7: $1/R$	8: $1/R^{1/2}$	9: 1
10: $R^{1/2}$	11: R	12: $R^{3/2}$
13: R^2	14: $R^{5/2}$	15: R^3
16: R^4	17: R^5	18: $e^{-R/2}$
19: e^{-R}	20: e^{-2R}	21: e^{-3R}
22: $e^{R/2}$	23: e^R	24: e^{2R}
25: e^{3R}	26: $(\ln R)^{-1/2}$	27: $(\ln R)^{-1}$
28: $(\ln R)^{-2}$	29: $(\ln R)^{-3}$	30: $(\ln R)^{1/2}$
31: $\ln R$	32: $(\ln R)^2$	33: $(\ln R)^3$

b. Specific Heat Data. Number of Runs Card. The first card read in gives the number of runs in the experiment. This is in column 9.

This is followed by the data for each run, one after another, each run containing the following data:

Number of Points Card. The first card of each run gives the number of specific heat points for that run in columns 8-9.

Constants Card. The second card gives the constants used in calculating the specific heats as follows:

Word 1: (col. 1-9)	Constant <u>r</u> of the formula for the heater resistance $R = r + sT$, in ohms.
Word 2: (col. 10-20)	Constant <u>s</u> of the formula for the heater resistance $R = r + sT$, in ohms/°K.
Word 3: (col. 21-31)	Value of standard resistor used to measure heating current in ohms.
Word 4: (col. 32-42)	Value of standard resistor used to measure thermometer current, in ohms.
Word 5: (col. 43-52)	Constant <u>A</u> of the formula for the heat capacity of the empty calorimeter $C = AT^3 + BT$, in millijoules/$(°K)^4$.
Word 6: (col. 53-62)	Constant <u>B</u> of the formula for the heat capacity of the empty calorimeter $C = AT^3 + BT$, in millijoules/$(°K)^2$.
Word 7: (col. 63-72)	Number of moles of sample.

The next cards of the run are the actual specific heat input consisting of drift data and heating period data alternately.

<u>Drift Data Card(s)</u>. The drift data is made up on as many cards as necessary (up to 4) as follows:

Word 1: (col. 8-9)	Number of drift points (if more than one card for drift, this number will appear on first card only).
Word 2: (col. 10-20)	Voltage of carbon thermometer.
Word 3: (col. 25-31)	Time reading for previous voltage measurement. Col. 25: hours; col. 26-28: minutes; col. 29-31: seconds.
Word 4: (col. 32-42)	Voltage of carbon thermometer.
Word 5: (col. 46-52)	Time reading for previous voltage measurement. Col. 46: hours; col. 47-49: minutes; col. 50-52: seconds.
Word 6: (col. 53-62)	Voltage of carbon thermometer.
Word 7: (col. 66-72)	Time reading for previous voltage measurement. Col. 66: hours; col. 67-69: minutes; col. 70-72: seconds.

Heading Period Card. The heating period data is made up as follows:

Word 1: (col. 1-9)	Voltage reading of current in carbon thermometer at some time during previous drift period.
Word 2: (col. 14-21)	Time reading for previous current measurement. Col. 14: hours; col. 15-17: minutes; col. 18-20: seconds.
Word 3: (col. 25-31)	Time reading at beginning of heating period. Col. 25: hours; col. 26-28: minutes; col. 29-31: seconds.
Word 4: (col. 32-42)	Voltage reading of heating current, in volts.
Word 5: (col. 46-52)	Length of heating period. Col. 46-49: seconds; col. 50-52: sixtieths of a second.
Word 6: (col. 58-62)	Code word as follows: Col. 58: Experiment number. Col. 59: Run number. Col. 60-62: Specific heat point number.

The last card of a run is a heating period card containing only the information of the first two words.

2. Machine Operation.

Reader: Standard 72-column.

Punch: Standard 72-column; used only when switch 6 is UP.

Printer: Standard SHARE 2 board; used only when switch 6 is UP.

Sense Switch Settings:

1: UP unless it is desired to stop after completion of calibration curve calculations.

2: UP unless it is desired to read input data (including He^3 and He^4 tables) from tape 2.

6: UP unless it is desired to put output on tape 6. The sense switch settings are interrogated repeatedly during input and output, and a change in their settings is usually immediately effective.

Tapes: Tape 2 contains input (including He^3 and He^4 tables) with switch 2 DOWN.

Tape 6 receives output with switch 6 DOWN.

Off-line Processing: Print and punch from tape 6 under program control.

Running Procedure: "Ready" code deck followed by He^3 and He^4 tables and data deck in card reader if switch 2 is UP.

If switch 2 is DOWN: "Ready" code deck in card reader and "Ready" data tape 2.

"Clear"

"Load Cards"

Problem is completed when all data are entered and HPR 77777 appears in storage lights.

To run data from another experiment without loading in code deck and He^3 and He^4 tables again:

If switch 2 is UP: "Ready" data deck in card reader.

Console switches: 000000000115

If switch 2 is DOWN: "Ready" data tape 2.

Console switches: 000000000225

Automatic-Manual Switch: Manual

"Enter Instruction"

Automatic-Manual Switch: Automatic

"Start"

Problem is completed as above.

3. Output

a. Magnetic Thermometer. This output gives first the values of the constants A and B determined by the least-squares analysis for the magnetic thermometer calibration curve, then the value of β which it was determined gave the best fit to the calibration formula [formula (1)].

After this, the values of T, R, and κ for the calibration points used in the least-squares analysis above are given along with the deviations of the experimental values of κ from the smooth curve. This deviation is of the form κ (formula evaluated at experimental temperature) - κ (experimental). Also given for each point is the code word for that point as described under input.

b. Calibration. For the main calibration curve the output consists of the coefficients as determined by the least-squares analysis, each coefficient followed by the code number for the function of R to which it applies. Then data for the actual calibration points are listed; the value of temperature, resistance, and two forms of the deviation of the experimental points from the formula determined are put out for each calibration point.

c. Specific Heat Analysis. For each experimental heating period, a specific heat point is calculated; the output of this calculation consists of the specific heat (not curvature corrected), the mean temperature, and the temperature increase ΔT for the heating period. Also included is a number indicating how well the temperature drift following the heating period is fitted by the straight line put through the drift points. This number is the mean of the square of the deviations of the experimental points from the straight line.

B. Curvature Correction Program

1. Input

The input to the curvature correction program consists primarily of the output of the specific heat calculation program. For each run of the previous specific heat calculations, the punched card output for that run contains the data, not only for the point plotter, but also for the input to the curvature correction program. The code word on these cards, in col. 51-60, serves to identify the data on the cards for the purpose of eliminating any points before proceeding with the least-squares fit of the data in the present program.

Title Card. The first card read in by the curvature correction program is a title card for the data. For this purpose, a title card is punched out for each run by the previous program. Care must be taken, therefore, to remove any extra title cards from the input data to the curvature correction program in the case that more than one run is being combined as input.

Specifications Card. The second card read in by the program contains the following:

Word 1: (col. 7-9)	The total number of specific heat points (up to 200) being put in as input.
Word 2: (col. 20)	The number of terms (up to 7) with floating coefficients desired to be used in the least-squares analysis.
Word 3: (col. 31)	The number of terms (up to 7) with constant coefficients desired to be used in the least-squares analysis.

Specific Heat Cards. The next cards read in are the desired number of specific heat cards as calculated and punched out from the previous program.

After the specific heat cards are the three cards specifying the actual formula to be used in fitting the specific heat points. All three cards are arranged in the same manner: words 1, 2, 3, 4, 5, 6, and 7 are in columns 1-9, 10-20, 21-31, 32-42, 43-52, 53-62, and 63-72, respectively.

Powers of T, Variable Coefficients. The first of these cards gives the powers of T for the terms of the formula whose coefficients are floating. This will require as many words on the card (up to 7) as are indicated in word 2 of the specifications card.

Powers of T, Constant Coefficients. The second card gives the powers of T for the terms of the formula whose coefficients are fixed. This will require as many words on the card (up to 7) as are indicated by word 3 of the specifications card.

Constant Coefficients Card. The last card of the curvature correction input gives the fixed coefficients of the terms of the formula whose powers of T are given in the corresponding word of the previous card.

2. Machine Operation

Reader: Standard 72-column.

Punch: Standard 72-column; used only when switch 6 is UP.

Printer: Standard SHARE 2 board; used only when switch 6 is UP.

Sense Switch Settings:

2: UP unless it is desired to read input from tape 2.

6: UP unless it is desired to put output on tape 6.

Tapes: Tape 2 contains input for use with switch 2 DOWN.

Tape 6 receives output with switch 6 DOWN.

Off-line Processing: Print and punch from tape 6 under program control.

Running Procedure: "Ready" code deck followed by data deck in card reader if switch 2 is UP.

If switch 2 is DOWN: "Ready" code deck in card reader and "Ready" data tape 2.

"Clear"

"Load Cards"

Problem is completed when HPR 77777 appears in storage lights.

To run program again with different data without loading in code deck again:

"Ready" data deck in card reader if switch 2 is UP.

If switch 2 is DOWN: "Ready" data tape 2.

Console switches: 000000000027

Automatic-Manual Switch: Manual

"Enter Instruction"

Automatic-Manual Switch: Automatic

"Start"

Problem is completed as above.

3. Output

The output of the curvature correction program gives the powers of T for which coefficients were determined by the least-squares analysis, the coefficients themselves, and the standard deviations of the coefficients. Also printed out for reference are the powers of T which had fixed coefficients along with those coefficients. Then is printed out the final values of specific heat which have now been curvature corrected, the mean temperatures for these specific heats, the temperature intervals of the heating period, and the deviations of the corrected specific heats from the smooth function determined by the least-squares analysis.

C. Point Plotter

For speed and accuracy in plotting the intermediate and final results of the various calculations performed by the program, the outputs of the several parts of the program have been made to include cards which can be fed into the Electronic Associates, Inc. DATAPLOTTER for automatic plotting of the points. In all cases, the data for the point plotter have been normalized in such a fashion that the largest number of any group or run is scaled until it is between 1.0 and 0.1 and the rest of the numbers of the group are scaled by the same factor. In this way, all input to the point plotter is in the form ±0.XXXXXXXX of which only the first four significant digits are used by the point plotter. This arrangement is necessary in order that the sign of the number is always in the same column of the card. However, it means that, when plotting data from several runs, different runs may be scaled differently and, therefore, the scale factor of the point plotter must be changed accordingly.

The contents of the output cards from the various parts of the program are as follows:

M.T.	T	K(F)-K(E)	R	KAPPA	OMIT	CODE
C.	T	T(F)-T(E)	R	$\frac{1}{T(F)} - \frac{1}{T(E)}$	OMIT	CODE
S.H.	T	C	(C)	(T)	(DELTA T)	CODE
C.C.	T	C	C(F)-C(E)		OMIT	CODE
DATA	±0.XXXXxxx	±0.XXXXxxx	±0.XXXXxxx	±0.XXXXxxx	1.0	ERnnn
CARD	123456789	0123456789	0123456789	0123456789	0123456789	01234567890
COL.		1	2	3	4	5 6

M.T. = Magnetic Thermometer Data
C. = Calibration Data
S.H. = Specific Heat Data
C.C. = Curvature Correction Data

The quantities in parentheses are those for the input to the curvature correction program and are not adapted for use on the point plotter.

The quantity marked <u>OMIT</u> consists of either a one or a zero, depending on whether the point in question has been used in the calculations or has been omitted, respectively. It is intended to be used for controlling the point symbol by which means omitted points would be indicated by a different symbol from the rest.

1. <u>Operating Instructions</u>

a. Place suitable graph paper on table of plotter. By hand, move arm up and down over paper until paper is lined up properly (path of cursor should be parallel to a vertical line). Turn VACUUM switch ON. Smooth out paper.

b. The following switches should be placed in the indicated positions:

Switch	Position
VACUUM	ON
LIGHT	ON
POWER	ON
BOARD	STANDBY
PEN	UP
INCREMENT ADVANCE	OFF
TAPE KEYBOARD, CARDS	TAPE KEYBOARD
XY NORMAL, REVERSE	NORMAL
POT SET	ZERO SET
PLOT SEQUENCE	A

NORMAL, NULL . . . . NORMAL
PEN, ARM . . . . ARM
AUTO, MANUAL . . . . neutral

c. Then, as follows:

BOARD. . . . . OPERATE
INCREMENT ADVANCE . . . . RESET
PLOT SELECTOR . . . . RESET
Rotate NULL SENSITIVITY . . . . completely clockwise
Depress STORAGE CLEAR
Depress STOP

d. Free locks on pen and arm helipots. By turning helipot knobs, set head above point of desired origin. Call this point (x_0, y_0). Lock helipots. Depress RESET switch. Point (x_0, y_0) has just been plotted.

e. Of the points to be plotted, select one nearest limit of machine. Call this point (x_m, y_m). Manually position head over location of this point.

Note: x_m, y_m must be greater than zero.

POT SET . . . . XSF

Depress STORAGE CLEAR

Type into keyboard: X, sign, $|x_m - x_0|$, PLOT

Note: on keyboard, + = 0
- = 1

Wait until null indicator light goes out.

POT SET . . . . YSF

Type into keyboard: Y, sign, $|y_m - y_0|$, PLOT

POT SET . . . . ZERO SET

Depress STOP
Depress RESET

Point (x_m, y_m) has just been plotted.

Depress STORAGE CLEAR
Depress STOP
Depress RESET

Point (x_0, y_0) has again been plotted.

f. With head at position (x_0, y_0),

POT SET . . . . XPX

Type into keyboard X-Parallax: X, sign, $|x_0|$, PLOT

Wait until null indicator light goes out.

POT SET . . . . YPX

Type into keyboard Y-Parallax: Y, sign, $|y_0|$, PLOT

When light goes out,

POT SET . . . . PLOT

The machine is now ready to accept points to plot.

Note: If the null indicator light fails to go out, set the BOARD switch to STANDBY, depress the STOP and RESET buttons, and return BOARD to OPERATE.

The available point symbols are the following:

0 1 2 3 4 5 6 7 8 9

To change point symbol, depress and keep down SYMBOL ADVANCE button, type into keyboard the appropriate number, release button.

2. <u>Data Input (IBM Cards)</u>

Card format is controlled by the board-wiring in the IBM-523 Summary Card Punch (card reader) as follows: number the first twelve horizontal entry points under <u>COMP MAG OR CTR. TOT. EXIT OR M.S. IN</u> as 1, 2, $\cdots$, 12. Then pulses to points 1-4 are interpreted as X-digits, 5-8 as Y-digits, 9 as the sign of X, 10 as the sign of Y, 11 as the symbol advance, and 12 as a control code (not used). Wire these holes from the desired card columns under PUNCH BRUSHES.

IV. PROGRAM DETAILS

A. <u>Magnetic Thermometer Calculation</u>

It is in this part of the program that the manometer pressure readings are converted to values of absolute temperatures. The formulas for converting the manometer readings to readings of absolute pressure in mm of mercury are:

For He^3 oil readings: $P = (P_2 - P_1)(0.078062 - 0.000058t)/C$ (3)

For He^3 Hg readings: $P = (P_2 - P_1 - Z)(0.999428 - 0.000172t)/C$ (4)

For He^4 oil readings: $P = (P_2 - P_1)(0.078062 - 0.000058t)$ (5)

For He^4 Hg readings: $P = (P_2 - P_1 - Z')(0.999428 - 0.000172t)$, (6)

where P_2 and P_1 are the manometer readings, t is the room temperature in °C, C is the correction factor for He^3 purity, Z is the He^3 mercury manometer zero correction, and Z' is the He^4 mercury manometer zero correction.

From the values of pressure thus determined, a table look-up is performed and a parabolic interpolation is made, using three adjacent points of the table. The He^3 table consists of values of absolute temperature and pressure in mm of Hg at intervals of 1 millidegree from 0.7 to 0.9°K, 5 millidegrees from 0.9 to 1.4°K, and 10 millidegrees from 1.4 to 2.19°K; the He^4 table has values at intervals of 10 millidegrees from 1.4 to 4.39°K. The points from the table used for the interpolation consist of two points above and one point below the unknown point. This means that He^3 points above 2.1792°K and He^4 points above 4.38°K exceed the effective limits of the tables.

In the least-squares analysis for the magnetic thermometer, the constant β of formula (1) is varied by units of 0.001 from -0.010 to +0.021; the value of β is picked which results in values of A and B from the least-squares analysis giving the best fit to the experimental points.

The least-squares analysis for the magnetic thermometer also has the provision for eliminating from the analysis those points whose deviations are abnormally large and which are therefore likely to be in error. This is done by performing the least-squares analysis once and then comparing the deviation of each point from the smooth curve thus determined with the deviations of the points immediately adjacent to the point. If the square of the deviation of the point in question is more than nine times the mean of the squares of the deviations of the two preceding and the two following points, then the point is thrown out and the analysis is repeated without it. Because of the nature of this elimination procedure, the two points at the beginning and the two at the end of a set of points are not considered for elimination.

B. Calibration

The calibration calculations are done in double precision to assure greater accuracy; the routine used is the General Electric Fortran II Double-Precision Floating Point Package GD-A-01-1. The least-squares analysis performed for the calibration curve has the same provision as described above for throwing out points whose deviations are too large.

In the least-squares analysis, the points used are weighted, the weight of each point being proportional to T so that, other things being equal, the deviations in T will tend to be proportional to T [the analysis is performed with a formula of the form $1/T = f(R)$].

C. Specific Heat Analysis

In the calculations of the specific heats, the program first calculates the constants for the straight lines of the fore- and after-drifts. From the equations for the drifts can be found the resistance of the carbon thermometer before and after the heat input extrapolated to the middle of the heating time. The method for this can be seen from the following analysis:

If the carbon thermometer circuit is considered as an impressed voltage E_b across a combination of the thermometer resistance R_T in series with another resistance R_s, then the current I flowing in the circuit can be expressed as

$$I = (E_b - E_T)/R_s \quad , \tag{7}$$

where E_T is the voltage appearing across the carbon thermometer. If the voltage across the thermometer at some time is found to be E_{T1}, and the current flowing through it at the same time is I_1, and if E_{T2} and I_2 are the voltage and current at some later time, then by a series of substitutions in equation (7), the following equation can be derived:

$$R_T = \frac{E_T(E_{T1} - E_{T2})}{(I_1(E_T - E_{T2}) - I_2(E_T - E_{T1})} \quad . \tag{8}$$

If, therefore, current readings I_1 and I_2 are taken at times t_{I1} and t_{I2} (one during each drift period), respectively, then the values of E_{T1} and E_{T2} can be determined by evaluating the fore-drift equation at $t = t_{I1}$ and the after-drift equation at $t = t_{I2}$, respectively. With these values, equation (8) can be used to find the resistance of the carbon thermometer for any values of E_T, in particular those values obtained by extrapolating the temperature drifts to the middle of the heating period. The calibration formula is then used to find the temperatures of these two points. This immediately yields the mean temperature and the temperature increase ΔT. It is a simple matter then to use this to calculate the specific heat according to the formula

$$C = \frac{\dfrac{I^2(r + sT)t}{\Delta T} - (AT^3 + BT)}{M} \quad , \tag{9}$$

where I is the heating current, r and s are the constants for the heater resistance, T is the mean temperature, t is the length of the heating period, A and B are the constants for the heat capacity of the empty calorimeter, and M is the number of moles of sample.

D. Curvature Correction

If the true specific heat of a substance follows the formula

$$C = AT^a + BT^b + \cdots + NT^n \quad , \tag{10}$$

then the amount of heat put into the substance to cause a temperature rise from T_1 to T_2 would be

$$q = \int_{T_1}^{T_2} (AT^a + BT^b + \cdots + NT^n)dT$$

$$= \frac{A}{a+1}(T_2^{a+1} - T_1^{a+1}) + \frac{B}{b+1}(T_2^{b+1} - T_1^{b+1}) + \cdots \tag{11}$$

$$+ \frac{N}{n+1}(T_2^{n+1} - T_1^{n+1}) \qquad (\text{providing } a, b, \cdots, n \neq -1) \quad .$$

The specific heat as calculated by the previous program would then be

$$C^* = \frac{q}{T_2 - T_1} = \frac{A(T_2^{a+1} - T_1^{a+1})}{(a+1)(T_2 - T_1)} + \frac{B(T_2^{b+1} - T_1^{b+1})}{(b+1)(T_2 - T_1)} + \cdots$$

$$+ \frac{N(T_2^{n+1} - T_1^{n+1})}{(n+1)(T_2 - T_1)} \quad . \tag{12}$$

Therefore, if the values of C^*, T, $T_2 - T_1$, and $a, \cdots, n$ are known (these will be recognized as the input to the curvature correction program), then a least-squares analysis can be performed on the basis of this equation to determine directly the coefficients A, B, $\cdots$, N. When the coefficients A, B, $\cdots$, N have been determined, then for any experimental value of C^*, T, and $T_2 - T_1$, the true, corrected experimental specific heat is

$$C = C^* + AT^a + BT^b + \cdots + NT^n - \frac{A(T_2^{a+1} - T_1^{a+1})}{(a+1)(T_2 - T_1)}$$

$$- \frac{B(T_2^{b+1} - T_1^{b+1})}{(b+1)(T_2 - T_1)} - \cdots - \frac{N(T_2^{n+1} - T_1^{n+1})}{(n+1)(T_2 - T_1)} \quad . \tag{13}$$

In performing the least-squares analysis for this part of the program, points with too large a deviation from the smooth curve are thrown out in the same manner as has been described for the previous least-squares calculations.

To prevent loss of accuracy occurring in the solution of the normal equations, double precision is also used in the calculations for this part of the program.

PROGRAM STOPS

The following list gives the SAP code for each program stop, along with the Fortran statement number of the stop instruction and the Fortran statement number of the instruction causing the transfer to the stop command.

Stop	St. No.	Orig. St. No.	Reason For Stop
HPR 1	999	M T 21-1	He^3 table exceeded.
HPR 2	998	M T 38-1	He^4 table exceeded.
HPR 4	996	M T 139	Negative temperature encountered.
HPR 5	995	M T 140	Temperature greater than 10°K encountered.
HPR 74	996	C 344	Negative temperature encountered.
HPR 75	995	C 345	Temperature greater than 10°K encountered.
HPR 11	412	C 411-1	Calibration calculations completed; sense switch 1 is DOWN.
HPR 64	996	C C 138-1	Negative temperature encountered.
HPR 65	995	C C 77	Temperature greater than 10°K encountered.

M T = Magnetic thermometer sub-program

C = Calibration sub-program

C C = Curvature correction sub-program

PROGRAM LISTING

```
  MAGNETIC THERMOMETER SUBPROGRAM
  DIMENSION TABLE3(2,380),TABLE4(2,300),B(8,9),A(8,9),COEFC(8),
 1R(100),T(100),OMIT(100),THERM(100),KIND(100),NCODE(100),DEV(100),
 2TDEV(100),LSFN(8),F(8),ARG(4),SCALE(4),NAME(12)
  COMMON R,T,NAME,NCODE,LSFN,F,COEFC
  IF (SENSE SWITCH 2) 2,4
4 READ 1,((TABLE3(I,J),I=1,2),J=1,380),((TABLE4(I,J),I=1,2),J=1,300)
  READ 3,(NAME(I),I=1,12)
  READ 5,NUMBER,ALPHA,H3HGZC,H4HGZC,H3PURC,RSTANR
  GO TO 9
2 READ INPUT TAPE 2,1,((TABLE3(I,J),I=1,2),J=1,380),((TABLE4(I,J),
 1I=1,2),J=1,300)
1 FORMAT (5(F7.4,F7.3))
  READ INPUT TAPE 2,3,(NAME(I),I=1,12)
3 FORMAT (12A6)
  READ INPUT TAPE 2,5,NUMBER,ALPHA,H3HGZC,H4HGZC,H3PURC,RSTANR
5 FORMAT (I9,F11.6,F11.2,F11.2,F10.6,F10.2)
9 DO 52 I=1,NUMBER
  IF (SENSE SWITCH 2) 6,7
7 READ 8,PRESS1,PRESS2,THERM(I),CURR,VOLT,RTEMP,KIND(I),NCODE(I)
  GO TO 10
6 READ INPUT TAPE 2,8,PRESS1,PRESS2,THERM(I),CURR,VOLT,RTEMP,
 1KIND(I),NCODE(I)
8 FORMAT (F9.2,F11.2,F11.2,F11.2,F10.2,F10.1,I3,I7)
10 KINDI=KIND(I)
  GO TO (11,13,15,17,52),KINDI
11 H3PRES=(PRESS2-PRESS1)*(0.078062-0.000058*RTEMP)/H3PURC
  GO TO 19
13 H3PRES=(PRESS2-PRESS1-H3HGZC)*(0.999428-0.000172*RTEMP)/H3PURC
  GO TO 19
15 H4PRES=(PRESS2-PRESS1)*(0.078062-0.000058*RTEMP)
  GO TO 36
17 H4PRES=(PRESS2-PRESS1-H4HGZC)*(0.999428-0.000172*RTEMP)
  GO TO 36
19 DO 21 J=2,379
  IF (TABLE3(1,J)-H3PRES) 21,23,25
21 CONTINUE
  GO TO 999
23 T(I)=TABLE3(2,J)
  GO TO 52
25 B(1,1)=TABLE3(1,J)-TABLE3(1,J-1)
  B(1,2)=B(1,1)*B(1,1)
  B(1,3)=TABLE3(2,J)-TABLE3(2,J-1)
  B(2,1)=TABLE3(1,J+1)-TABLE3(1,J-1)
  B(2,2)=B(2,1)*B(2,1)
  B(2,3)=TABLE3(2,J+1)-TABLE3(2,J-1)
  DENOM=B(1,1)*B(2,2)-B(2,1)*B(1,2)
  BINT=(B(1,3)*B(2,2)-B(2,3)*B(1,2))/DENOM
  CINT=(B(1,1)*B(2,3)-B(2,1)*B(1,3))/DENOM
  T(I)=BINT*(H3PRES-TABLE3(1,J-1))+CINT*(H3PRES-TABLE3(1,J-1))
 1*(H3PRES-TABLE3(1,J-1))+TABLE3(2,J-1)
  GO TO 52
```

```
 38 CONTINUE
    GO TO 998
 40 T(I)=TABLE4(2,J)
    GO TO 52
 42 B(1,1)=TABLE4(1,J)-TABLE4(1,J-1)
    B(1,2)=B(1,1)*B(1,1)
    B(1,3)=TABLE4(2,J)-TABLE4(2,J-1)
    B(2,1)=TABLE4(1,J+1)-TABLE4(1,J-1)
    B(2,2)=B(2,1)*B(2,1)
    B(2,3)=TABLE4(2,J+1)-TABLE4(2,J-1)
    DENOM=B(1,1)*B(2,2)-B(2,1)*B(1,2)
    BINT=(B(1,3)*B(2,2)-B(2,3)*B(1,2))/DENOM
    CINT=(B(1,1)*B(2,3)-B(2,1)*B(1,3))/DENOM
    T(I)=BINT*(H4PRES-TABLE4(1,J-1))+CINT*(H4PRES-TABLE4(1,J-1))
   1*(H4PRES-TABLE4(1,J-1))+TABLE4(2,J-1)
 52 R(I)=(VOLT*RSTANR)/CURR
    BETA=-0.010
    RMSDEV=99999999.0
 55 B(1,1)=0.0
    B(1,2)=0.0
    B(1,3)=0.0
    B(2,1)=0.0
    B(2,2)=0.0
    B(2,3)=0.0
    NOMAGN=1
    DO 72 I=1,NUMBER
    IF (THERM(I)) 63,72,63
 63 KINDI=KIND(I)
    NOMAGN=2
    GO TO (65,65,65,65,72),KINDI
 65 XKAPPA=1.0/(T(I)+ALPHA/T(I)+BETA)
    B(1,1)=B(1,1)+1.0
    B(1,2)=B(1,2)+XKAPPA
    B(1,3)=B(1,3)+THERM(I)
    B(2,1)=B(1,2)
    B(2,2)=B(2,2)+XKAPPA*XKAPPA
    B(2,3)=B(2,3)+XKAPPA*THERM(I)
 72 CONTINUE
    GO TO (219,74),NOMAGN
 74 DENOM=B(1,1)*B(2,2)-B(2,1)*B(1,2)
    THERMA=(B(1,3)*B(2,2)-B(2,3)*B(1,2))/DENOM
    THERMB=(B(1,1)*B(2,3)-B(2,1)*B(1,3))/DENOM
    P=0.0
    SDEV=0.0
    DO 87 I=1,NUMBER
    IF (THERM(I)) 80,86,80
 80 KINDI=KIND(I)
    GO TO (82,82,82,82,86),KINDI
 82 DEV(I)=THERMA+THERMB/(T(I)+ALPHA/T(I)+BETA)-THERM(I)
    SDEV=SDEV+DEV(I)*DEV(I)
    P=P+1.0
    GO TO 87
```

```
 86 DEV(I)=0.0
 87 CONTINUE
    TMSDEV=SDEV/P
    IF (RMSDEV-TMSDEV) 90,90,93
 90 IF (BETA-0.020) 91,103,103
 91 BETA=BETA+0.001
    GO TO 55
 93 DO 94 I=1,NUMBER
 94 TDEV(I)=DEV(I)
    RBETA=BETA
    RMSDEV=TMSDEV
    DO 99 J=1,2
    DO 99 K=1,3
 99 A(J,K)=B(J,K)
    RTHA=THERMA
    RTHB=THERMB
    GO TO 90
103 M=1
    OMIT(1)=1.0
    OMIT(2)=1.0
    OMIT(NUMBER-1)=1.0
    OMIT(NUMBER)=1.0
    DO 155 I=1,NUMBER
    IF (THERM(I)) 110,155,110
110 KINDI=KIND(I)
    GO TO (112,112,112,112,155),KINDI
112 TM1=0.0
    TM2=0.0
    TP1=10.0
    TP2=10.0
    DO 138 J=1,NUMBER
    IF (THERM(J)) 118,138,118
118 KINDJ=KIND(J)
    GO TO (120,120,120,120,138),KINDJ
120 IF (T(I)-T(J)) 121,138,130
121 IF (T(J)-TP2) 122,122,138
122 IF (T(J)-TP1) 125,125,123
123 TP2=T(J)
    NP2=J
    GO TO 138
125 TP2=TP1
    NP2=NP1
    TP1=T(J)
    NP1=J
    GO TO 138
130 IF (T(J)-TM2) 138,131,131
131 IF (T(J)-TM1) 132,132,134
132 TM2=T(J)
    NM2=J
    GO TO 138
134 TM2=TM1
    NM2=NM1
    TM1=T(J)
    NM1=J
```

```
138 CONTINUE
139 IF (TM2) 996,144,140
140 IF (TP2-10.0) 141,144,995
141 AVDEV= (TDEV(NM2)*TDEV(NM2)+TDEV(NM1)*TDEV(NM1)+TDEV(NP1)
   1*TDEV(NP1)+TDEV(NP2)*TDEV(NP2))/4.0
    ABSMD=TDEV(I)*TDEV(I)
    IF (ABSMD-9.0*AVDEV) 144,146,146
144 OMIT(I)=1.0
    GO TO 155
146 OMIT(I)=0.0
    M=2
    XKAPPA=1.0/(T(I)+ALPHA/T(I)+RBETA)
    A(1,1)=A(1,1)-1.0
    A(1,2)=A(1,2)-XKAPPA
    A(2,1)=A(1,2)
    A(2,2)=A(2,2)-XKAPPA*XKAPPA
    A(1,3)=A(1,3)-THERM(I)
    A(2,3)=A(2,3)-XKAPPA*THERM(I)
155 CONTINUE
    GO TO (147,157),M
157 DENOM=A(1,1)*A(2,2)-A(2,1)*A(1,2)
    RTHA=(A(1,3)*A(2,2)-A(2,3)*A(1,2))/DENOM
    RTHB=(A(1,1)*A(2,3)-A(2,1)*A(1,3))/DENOM
    DO 156 I=1,NUMBER
    IF (THERM(I)) 158,156,158
158 KINDI=KIND(I)
    GO TO (159,159,159,159,156),KINDI
159 TDEV(I)=RTHA+RTHB/(T(I)+ALPHA/T(I)+RBETA)-THERM(I)
156 CONTINUE
147 IF (SENSE SWITCH 6) 160,148
148 PRINT 161,(NAME(I),I=1,12)
    PRINT 163
    PRINT 165,RTHA,RTHB,ALPHA,RBETA
    PRINT 167
    GO TO 168
160 WRITE OUTPUT TAPE 6,161,(NAME(I),I=1,12)
161 FORMAT (1H112A6)
    WRITE OUTPUT TAPE 6,163
163 FORMAT (/26H MAGNETIC THERMOMETER DATA)
    WRITE OUTPUT TAPE 6,165,RTHA,RTHB,ALPHA,RBETA
165 FORMAT (/5H A = F10.3,7H   B = F10.4,11H   ALPHA = F9.6,
   110H   BETA = F8.4)
    WRITE OUTPUT TAPE 6,167
167 FORMAT (/46H T (DEG K)    R (OHMS)     KAPPA      K(F)-K(E)/120X)
168 ARG(1)=0.0
    ARG(2)=0.0
    ARG(3)=0.0
    ARG(4)=0.0
    DO 185 I=1,NUMBER
    IF (THERM(I)) 174,185,174
174 KINDI=KIND(I)
    GO TO (177,177,177,177,185),KINDI
```

```
177 IF (ABSF(T(I))-ARG(1)) 179,179,178
178 ARG(1)=ABSF(T(I))
179 IF (ABSF(R(I))-ARG(2)) 181,181,180
180 ARG(2)=ABSF(R(I))
181 IF (ABSF(THERM(I))-ARG(3)) 183,183,182
182 ARG(3)=ABSF(THERM(I))
183 IF (ABSF(TDEV(I))-ARG(4)) 185,185,184
184 ARG(4)=ABSF(TDEV(I))
185 CONTINUE
    DO 195 I=1,4
    SCALE(I)=1.0
    IF (ARG(I)-1.0) 190,191,192
188 ARG(I)=ARG(I)*10.0
    SCALE(I)=SCALE(I)*10.0
190 IF (ARG(I)-0.1) 188,195,195
191 SCALE(I)=SCALE(I)/10.0
192 ARG(I)=ARG(I)/10.0
    SCALE(I)=SCALE(I)/10.0
    IF (ARG(I)-1.0) 195,192,192
195 CONTINUE
    DO 211 I=1,NUMBER
    IF (THERM(I)) 198,211,198
198 KINDI=KIND(I)
    GO TO (199,199,199,199,211),KINDI
199 IF (SENSE SWITCH 6) 200,206
206 IF (OMIT(I)) 994,208,207
207 PRINT 202,T(I),R(I),THERM(I),TDEV(I),NCODE(I)
    GO TO 205
208 PRINT 204,T(I),R(I),THERM(I),TDEV(I),NCODE(I)
    GO TO 205
200 IF (OMIT(I)) 994,203,201
201 WRITE OUTPUT TAPE 6,202,T(I),R(I),THERM(I),TDEV(I),NCODE(I)
202 FORMAT (1H F9.7,F13.5,F11.4,F13.5,I12)
    GO TO 205
203 WRITE OUTPUT TAPE 6,204,T(I),R(I),THERM(I),TDEV(I),NCODE(I)
204 FORMAT (1H F9.7,F13.5,F11.4,F13.5,I12,9H     OMIT)
205 PP1=T(I)*SCALE(1)
    PP2=R(I)*SCALE(2)
    PP3=THERM(I)*SCALE(3)
    PP4=TDEV(I)*SCALE(4)
    IF (SENSE SWITCH 6) 209,212
212 PUNCH 213,PP1,PP4,PP2,PP3,OMIT(I),NCODE(I)
213 FORMAT (F10.7,F10.7,F10.7,F10.7,F10.1,I10)
    GO TO 211
209 WRITE OUTPUT TAPE 6,210,PP1,PP4,PP2,PP3,OMIT(I),NCODE(I)
210 FORMAT (1HQF10.7,F10.7,F10.7,F10.7,F10.1,I10)
211 CONTINUE
    CALL DP(20000)
    DO 217 I=1,NUMBER
    KINDI=KIND(I)
    GO TO (217,217,217,217,216),KINDI
216 T(I)=((RTHB-(THERM(I)-RTHA)*RBETA)+SQRTF((RTHB-(THERM(I)-RTHA)
   1*RBETA)*(RTHB-(THERM(I)-RTHA)*RBETA)-4.0*(THERM(I)-RTHA)*ALPHA
   2*(THERM(I)-RTHA)))/(2.0*(THERM(I)-RTHA))
```

```
217 CONTINUE
    CALL LVE
219 CALL CALIB(NUMBER)
    IF (SENSE SWITCH 6) 220,221
220 END FILE 6
221 STOP 77777
999 STOP 01
998 STOP 02
996 STOP 04
995 STOP 05
994 STOP 06
    END(0,1,0,0,1)
```

```
      SUBROUTINE CALIB(NUMBER)
      DIMENSION LSFN(8),F(8),R(100),T(100),A(8,9),B(8,9),COEFC(8),
     1DEV(100),TDEV(100),OMIT(100),ARG(4),SCALE(4),NCODE(100),NAME(12)
      COMMON R,T,NAME,NCODE,LSFN,F,COEFC
      IF (SENSE SWITCH 2) 219,218
  218 READ 220,NCONST,(LSFN(I),I=1,NCONST)
      GO TO 221
  219 READ INPUT TAPE 2,220,NCONST,(LSFN(I),I=1,NCONST)
  220 FORMAT (I9,I7,I4,I7,I4,I6,I5,I5,I5)
  221 CALL DP(20000)
      NC1=NCONST+1
      DO 226 I=1,NCONST
      DO 226 J=1,NC1
  226 B(I,J)=0.0
      DO 304 L=1,NUMBER
      CALL LSQFN(NCONST,L)
  300 W=T(L)
      F(NC1)=1.0/T(L)
      DO 304 I=1,NCONST
      DO 304 J=1,NC1
  304 B(I,J)=B(I,J)+F(I)*F(J)*W
      M=1
  306 DO 308 I=1,NCONST
      DO 308 J=1,NC1
  308 A(I,J)=B(I,J)
      NCM1=NCONST-1
      DO 318 K=1,NCM1
      L=K+1
      DO 318 I=L,NCONST
      IF (A(I,K)) 314,318,314
  314 QUOT=A(K,K)/A(I,K)
      DO 317 J=L,NC1
      A(I,J)=A(I,J)*QUOT-A(K,J)
  317 CONTINUE
  318 CONTINUE
      J=NCONST
      COEFC(J)=A(J,NC1)/A(J,J)
  320 SIGMA=0.0
      DO 322 I=J,NCONST
  322 SIGMA=SIGMA+COEFC(I)*A(J-1,I)
      COEFC(J-1)=(A(J-1,NC1)-SIGMA)/A(J-1,J-1)
      J=J-1
      IF (J-1) 993,326,320
  326 DO 333 I=1,NUMBER
      CALL LSQFN(NCONST,I)
  329 TCALC=0.0
      DO 333 J=1,NCONST
      TCALC=TCALC+COEFC(J)*F(J)
      DEV(I)=TCALC-1.0/T(I)
  333 TDEV(I)=1.0/TCALC-T(I)
      GO TO (335,364),M
  335 OMIT(1)=1.0
      OMIT(2)=1.0
      OMIT(NUMBER-1)=1.0
```

```
      OMIT(NUMBER)=1.0
      N=2
      DO 360 I=1,NUMBER
  112 TM1=0.0
      TM2=0.0
      TP1=10.0
      TP2=10.0
      DO 138 J=1,NUMBER
  120 IF (T(I)-T(J)) 121,138,130
  121 IF (T(J)-TP2) 122,122,138
  122 IF (T(J)-TP1) 125,125,123
  123 TP2=T(J)
      NP2=J
      GO TO 138
  125 TP2=TP1
      NP2=NP1
      TP1=T(J)
      NP1=J
      GO TO 138
  130 IF (T(J)-TM2) 138,131,131
  131 IF (T(J)-TM1) 132,132,134
  132 TM2=T(J)
      NM2=J
      GO TO 138
  134 TM2=TM1
      NM2=NM1
      TM1=T(J)
      NM1=J
  138 CONTINUE
  344 IF (TM2) 996,349,345
  345 IF (TP2-10.0) 346,349,995
  346 AVDEV=(DEV(NM2)*DEV(NM2)+DEV(NM1)*DEV(NM1)+DEV(NP1)*DEV(NP1)
     1+DEV(NP2)*DEV(NP2))/4.0
      ABSMD=DEV(I)*DEV(I)
      IF (ABSMD-9.0*AVDEV) 349,351,351
  349 OMIT(I)=1.0
      GO TO 360
  351 OMIT(I)=0.0
      N=3
      CALL LSQFN(NCONST,I)
  355 W=-T(I)
      F(NC1)=1.0/T(I)
      DO 359 J=1,NCONST
      DO 359 K=1,NC1
  359 B(J,K)=B(J,K)+F(J)*F(K)*W
  360 CONTINUE
      IF (N-2) 993,364,362
  362 M=2
      GO TO 306
  364 CALL LVE
      IF (SENSE SWITCH 6) 366,365
  365 PRINT 367,(NAME(I),I=1,12)
```

```
      PRINT 368
      PRINT 370,((COEFC(I),LSFN(I)),I=1,NCONST)
      PRINT 372
      GO TO 373
  366 WRITE OUTPUT TAPE 6,367,(NAME(I),I=1,12)
  367 FORMAT (1H112A6)
      WRITE OUTPUT TAPE 6,368
  368 FORMAT (/35H TEMPERATURE CALIBRATION CURVE DATA/120X)
      WRITE OUTPUT TAPE 6,370,((COEFC(I),LSFN(I)),I=1,NCONST)
  370 FORMAT (1H E15.8,I7)
      WRITE OUTPUT TAPE 6,372
  372 FORMAT (/51H T (DEG K)     R (OHMS)    1/T(F)-1/T(E)     T(F)-T(E)
     1/120X)
  373 ARG(1)=0.0
      ARG(2)=0.0
      ARG(3)=0.0
      ARG(4)=0.0
      DO 386 I=1,NUMBER
      IF (ABSF(T(I))-ARG(1)) 380,380,379
  379 ARG(1)=ABSF(T(I))
  380 IF (ABSF(R(I))-ARG(2)) 382,382,381
  381 ARG(2)=ABSF(R(I))
  382 IF (ABSF(TDEV(I))-ARG(3)) 384,384,383
  383 ARG(3)=ABSF(TDEV(I))
  384 IF (ABSF(DEV(I))-ARG(4)) 386,386,385
  385 ARG(4)=ABSF(DEV(I))
  386 CONTINUE
      DO 397 I=1,4
      SCALE(I)=1.0
      IF (ARG(I)-1.0) 392,393,394
  390 ARG(I)=ARG(I)*10.0
      SCALE(I)=SCALE(I)*10.0
  392 IF (ARG(I)-0.1) 390,397,397
  393 SCALE(I)=SCALE(I)/10.0
  394 ARG(I)=ARG(I)/10.0
      SCALE(I)=SCALE(I)/10.0
      IF (ARG(I)-1.0) 397,394,394
  397 CONTINUE
      DO 411 I=1,NUMBER
      IF (SENSE SWITCH 6) 399,398
  398 IF (OMIT(I)) 992,407,406
  406 PRINT 401,T(I),R(I),DEV(I),TDEV(I),NCODE(I)
      GO TO 405
  407 PRINT 404,T(I),R(I),DEV(I),TDEV(I),NCODE(I)
      GO TO 405
  399 IF (OMIT(I)) 992,403,400
  400 WRITE OUTPUT TAPE 6,401,T(I),R(I),DEV(I),TDEV(I),NCODE(I)
  401 FORMAT (1H F9.7,F13.5,F15.8,F13.8,I12)
      GO TO 405
  403 WRITE OUTPUT TAPE 6,404,T(I),R(I),DEV(I),TDEV(I),NCODE(I)
  404 FORMAT (1H F9.7,F13.5,F15.8,F13.8,I12,9H     OMIT)
  405 PP1=T(I)*SCALE(1)
      PP2=R(I)*SCALE(2)
      PP3=TDEV(I)*SCALE(3)
```

```
      PP4=DEV(I)*SCALE(4)
      IF (SENSE SWITCH 6) 409,408
  408 PUNCH 420,PP1,PP3,PP2,PP4,OMIT(I),NCODE(I)
  420 FORMAT (F10.7,F10.7,F10.7,F10.7,F10.1,I10)
      GO TO 411
  409 WRITE OUTPUT TAPE 6,410,PP1,PP3,PP2,PP4,OMIT(I),NCODE(I)
  410 FORMAT (1HQF10.7,F10.7,F10.7,F10.7,F10.1,I10)
  411 CONTINUE
      IF (SENSE SWITCH 1) 991,413
  996 STOP 74
  995 STOP 75
  993 STOP 07
  992 STOP 10
  991 IF (SENSE SWITCH 6) 416,412
  416 END FILE 6
  412 STOP 11
  413 IF (SENSE SWITCH 2) 418,417
  417 READ 414,NRUNS
      GO TO 419
  418 READ INPUT TAPE 2,414,NRUNS
  414 FORMAT (I9)
  419 DO 415 I=1,NRUNS
      CALL SPHTFN(NCONST)
  415 CONTINUE
      RETURN
      END(0,1,0,0,1)
```

```
      SUBROUTINE SPHTFN(NCONST)
      DIMENSION EDRIFT(12),DTIMEH(12),DTIMEM(12),DTIMES(12),DEV(12),
     1NCODE(200),COEFC(8),F(8),ARG(2),SCALE(2),CP(200),T(199),DELTAT
     2(200),NDUMMY(100),NAME(12),R(1),LSFN(8)
      COMMON R,T,NAME,NDUMMY,LSFN,F,COEFC
      IF (SENSE SWITCH 2) 414,413
  413 READ 415,NLOOP
      READ 417,HRESA,HRESB,RSTANH,RSTANR,CALA,CALB,XMOLES
      GO TO 418
  414 READ INPUT TAPE 2,415,NLOOP
  415 FORMAT (I9)
      READ INPUT TAPE 2,417,HRESA,HRESB,RSTANH,RSTANR,CALA,CALB,XMOLES
  417 FORMAT (F9.3,F11.4,F11.2,F11.2,F10.4,F10.4,F10.6)
  418 LVED=1
  419 RAK=1.0
      RBK=0.0
      RCK=0.0
      RDK=0.0
      REK=0.0
      RFK=0.0
      IF (SENSE SWITCH 2) 425,424
  424 READ 426,NDRIFT,(EDRIFT(I),DTIMEH(I),DTIMEM(I),DTIMES(I),
     1I=1,NDRIFT)
      GO TO 427
  425 READ INPUT TAPE 2,426,NDRIFT,(EDRIFT(I),DTIMEH(I),DTIMEM(I),
     1DTIMES(I),I=1,NDRIFT)
  426 FORMAT (I9,F11.2,F5.0,F3.0,F3.0,F11.2,F4.0,F3.0,F3.0,F10.2,F4.0,
     1F3.0,F3.0,3(/  F20.2,F5.0,F3.0,F3.0,F11.2,F4.0,F3.0,F3.0,F10.2,
     2F4.0,F3.0,F3.0))
  427 DO 428 I=1,NDRIFT
  428 DTIMES(I)=DTIMES(I)+60.0*(DTIMEM(I)+60.0*DTIMEH(I))
      DO 435 I=2,NDRIFT
      RAK=RAK+1.0
      RBK=RBK+DTIMES(I)-DTIMES(1)
      RCK=RBK
      RDK=RDK+(DTIMES(I)-DTIMES(1))*(DTIMES(I)-DTIMES(1))
      REK=REK+EDRIFT(I)-EDRIFT(1)
  435 RFK=RFK+(EDRIFT(I)-EDRIFT(1))*(DTIMES(I)-DTIMES(1))
      DENOM=RAK*RDK-RCK*RBK
      YD2=(RAK*RFK-RCK*REK)/DENOM
      XD2=(REK*RDK-RFK*RBK)/DENOM+EDRIFT(1)-YD2*DTIMES(1)
      SDEV=0.0
      DO 442 I=1,NDRIFT
      DEV(I)=XD2+YD2*DTIMES(I)-EDRIFT(I)
  442 SDEV=SDEV+DEV(I)*DEV(I)
      DNBR=NDRIFT
      SDEV=SDEV/DNBR
      GO TO (445,467),LVED
  445 IF (SENSE SWITCH 6) 446,444
  444 PRINT 447,(NAME(I),I=1,12)
      PRINT 448
      PRINT 450
      PRINT 452,SDEV
      PUNCH 460,(NAME(I),I=1,12)
```

```
460 FORMAT (12A6)
    GO TO 453
446 WRITE OUTPUT TAPE 6,447,(NAME(I),I=1,12)
447 FORMAT (1H112A6)
    WRITE OUTPUT TAPE 6,449,(NAME(I),I=1,12)
449 FORMAT (1HQ12A6)
    WRITE OUTPUT TAPE 6,448
448 FORMAT (/33H UNCORRECTED SPECIFIC HEAT OUTPUT)
    WRITE OUTPUT TAPE 6,450
450 FORMAT (/51H   C (MJ)      T (DEG K)      DELTA T
   1/120X)
    WRITE OUTPUT TAPE 6,452,SDEV
452 FORMAT (37X,F14.3)
453 LVEHTG=1
    K=0
456 IF (SENSE SWITCH 2) 454,457
457 READ 455,RESI2,TRESIH,TRESIM,TRESIS,BTIMEH,BTIMEM,BTIMES,EHTG2,
   1HTIMES,HTIMEF,NCODE(K+1)
    GO TO 458
454 READ INPUT TAPE 2,455,RESI2,TRESIH,TRESIM,TRESIS,BTIMEH,BTIMEM,
   1BTIMES,EHTG2,HTIMES,HTIMEF,NCODE(K+1)
455 FORMAT (F9.2,F5.0,F3.0,F3.0,F5.0,F3.0,F3.0,F11.5,F7.0,F3.0,I10)
458 RESI2=RESI2/RSTANR
    TRESI2=TRESIS+60.0*(TRESIM+60.0*TRESIH)
    BTIME2=BTIMES+60.0*(BTIMEM+60.0*BTIMEH)
    HTIME2=HTIMES+HTIMEF/60.0
    EHTG2=EHTG2/RSTANH
    GO TO (462,474),LVEHTG
462 ARG(1)=0.0
    ARG(2)=0.0
    DO 509 K=1,NLOOP
    YD1=YD2
    XD1=XD2
    LVED=2
    GO TO 419
467 RESI1=RESI2
    TRESI1=TRESI2
    BTIME1=BTIME2
    EHTG1=EHTG2
    HTIME1=HTIME2
    LVEHTG=2
    GO TO 456
474 ERESI1=XD1+YD1*TRESI1
    ERESI2=XD2+YD2*TRESI2
    TIMEAN=BTIME1+HTIME1/2.0
    EXTE1=XD1+YD1*TIMEAN
    EXTE2=XD2+YD2*TIMEAN
    EXTR1=EXTE1*(ERESI1-ERESI2)/(RESI1*(EXTE1-ERESI2)-RESI2*(EXTE1
   1-ERESI1))
    EXTR2=EXTE2*(ERESI1-ERESI2)/(RESI1*(EXTE2-ERESI2)-RESI2*(EXTE2
   1-ERESI1))
    CALL DP(20000)
```

```
      R(1)=EXTR1
      CALL LSQFN(NCONST,1)
      CALL LVE
  485 TEMP1=0.0
      DO 487 J=1,NCONST
  487 TEMP1=TEMP1+COEFC(J)*F(J)
      TEMP1=1.0/TEMP1
      CALL DP(20000)
      R(1)=EXTR2
      CALL LSQFN(NCONST,1)
      CALL LVE
  491 TEMP2=0.0
      DO 493 J=1,NCONST
  493 TEMP2=TEMP2+COEFC(J)*F(J)
      TEMP2=1.0/TEMP2
      T(K)=(TEMP1+TEMP2)/2.0
      CPCAL=(CALA*T(K)*T(K)+CALB)*T(K)
      DELTAT(K)=TEMP2-TEMP1
      RESHTR=HRESA+HRESB*T(K)
      CP(K)=(EHTG1*EHTG1*RESHTR*HTIME1/DELTAT(K)*1000.0-CPCAL)/XMOLES
      IF (SENSE SWITCH 6) 501,500
  500 PRINT 502,CP(K),T(K),DELTAT(K),SDEV,NCODE(K)
      GO TO 503
  501 WRITE OUTPUT TAPE 6,502,CP(K),T(K),DELTAT(K),SDEV,NCODE(K)
  502 FORMAT (1H F10.5,F13.8,F13.8,F14.3,I12)
  503 IF (ABSF(CP(K))-ARG(1)) 505,505,504
  504 ARG(1)=ABSF(CP(K))
  505 IF (ABSF(T(K))-ARG(2)) 509,509,506
  506 ARG(2)=ABSF(T(K))
  509 CONTINUE
      DO 520 I=1,2
      SCALE(I)=1.0
      IF (ARG(I)-1.0) 515,516,517
  513 ARG(I)=ARG(I)*10.0
      SCALE(I)=SCALE(I)*10.0
  515 IF (ARG(I)-0.1) 513,520,520
  516 SCALE(I)=SCALE(I)/10.0
  517 ARG(I)=ARG(I)/10.0
      SCALE(I)=SCALE(I)/10.0
      IF (ARG(I)-1.0) 520,517,517
  520 CONTINUE
      DO 526 K=1,NLOOP
      PP1=CP(K)*SCALE(1)
      PP2=T(K)*SCALE(2)
      IF (SENSE SWITCH 6) 524,523
  523 PUNCH 527,PP2,PP1,CP(K),T(K),DELTAT(K),NCODE(K)
  527 FORMAT (F10.7,F10.7,F10.5,F10.7,F10.7,I10)
      GO TO 526
  524 WRITE OUTPUT TAPE 6,525,PP2,PP1,CP(K),T(K),DELTAT(K),NCODE(K)
  525 FORMAT (1HQF10.7,F10.7,F10.5,F10.7,F10.7,I10)
  526 CONTINUE
      RETURN
      END(0,1,0,0,1)
```

```
      SUBROUTINE LSQFN(NCONST,L)
      DIMENSION R(100),T(100),NCODE(100),LSFN(8),F(8),COEFC(8),NAME(12)
      COMMON R,T,NAME,NCODE,LSFN,F,COEFC
  229 DO 298 I=1,NCONST
      LSFNI=LSFN(I)
      GO TO (232,234,236,238,240,242,244,246,248,250,252,254,256,258,
     1260,262,264,266,268,270,272,274,276,278,280,282,284,286,288,290,
     2292,294,296),LSFNI
  232 F(I)=1.0/(R(L)*R(L)*R(L)*R(L)*R(L))
      GO TO 298
  234 F(I)=1.0/(R(L)*R(L)*R(L)*R(L))
      GO TO 298
  236 F(I)=1.0/(R(L)*R(L)*R(L))
      GO TO 298
  238 F(I)=1.0/(R(L)*R(L)*SQRTF(R(L)))
      GO TO 298
  240 F(I)=1.0/(R(L)*R(L))
      GO TO 298
  242 F(I)=1.0/(R(L)*SQRTF(R(L)))
      GO TO 298
  244 F(I)=1.0/R(L)
      GO TO 298
  246 F(I)=1.0/SQRTF(R(L))
      GO TO 298
  248 F(I)=1.0
      GO TO 298
  250 F(I)=SQRTF(R(L))
      GO TO 298
  252 F(I)=R(L)
      GO TO 298
  254 F(I)=R(L)*SQRTF(R(L))
      GO TO 298
  256 F(I)=R(L)*R(L)
      GO TO 298
  258 F(I)=R(L)*R(L)*SQRTF(R(L))
      GO TO 298
  260 F(I)=R(L)*R(L)*R(L)
      GO TO 298
  262 F(I)=R(L)*R(L)*R(L)*R(L)
      GO TO 298
  264 F(I)=R(L)*R(L)*R(L)*R(L)*R(L)
      GO TO 298
  266 F(I)=1.0/EXPF(R(L)/2.0)
      GO TO 298
  268 F(I)=1.0/EXPF(R(L))
      GO TO 298
  270 F(I)=1.0/EXPF(2.0*R(L))
      GO TO 298
  272 F(I)=1.0/EXPF(3.0*R(L))
      GO TO 298
  274 F(I)=EXPF(R(L)/2.0)
      GO TO 298
```

```
276 F(I)=EXPF(R(L))
    GO TO 298
278 F(I)=EXPF(2.0*R(L))
    GO TO 298
280 F(I)=EXPF(3.0*R(L))
    GO TO 298
282 F(I)=1.0/SQRTF(LOGF(R(L)))
    GO TO 298
284 F(I)=1.0/LOGF(R(L))
    GO TO 298
286 F(I)=1.0/(LOGF(R(L))*LOGF(R(L)))
    GO TO 298
288 F(I)=1.0/(LOGF(R(L))*LOGF(R(L))*LOGF(R(L)))
    GO TO 298
290 F(I)=SQRTF(LOGF(R(L)))
    GO TO 298
292 F(I)=LOGF(R(L))
    GO TO 298
294 F(I)=LOGF(R(L))*LOGF(R(L))
    GO TO 298
296 F(I)=LOGF(R(L))*LOGF(R(L))*LOGF(R(L))
298 CONTINUE
    RETURN
    END(0,1,0,0,1)
```

```
      PAT ROACH CURVATURE CORRECTION PROGRAM
      DIMENSIONT(200),CP(200),DT(200),NCODE(200),DEV(200),OMIT(200),
     XNAME(12),ARG(3),SCALE(3),A(7,15),B(7,15),VCOEFS(7),CCOEFS(7),
     XCOEFW(7,15),STD(7),CPFN(8),PVAR(7),PCONST(7)
      IF(SENSESWITCH2)2,1
    1 READ3,(NAME(I),I=1,12)
      READ5,NUMBER,NVAR,NCONST
      READ7,(CP(I),T(I),DT(I),NCODE(I),I=1,NUMBER)
      READ9,(PVAR(I),I=1,NVAR)
      READ11,(PCONST(I),I=1,NCONST)
      READ13,(CCOEFS(I),I=1,NCONST)
      GOTO14
    2 READINPUTTAPE2,3,(NAME(I),I=1,12)
    3 FORMAT(12A6)
      READINPUTTAPE2,5,NUMBER,NVAR,NCONST
    5 FORMAT(I9,I11,I11)
      READINPUTTAPE2,7,(CP(I),T(I),DT(I),NCODE(I),I=1,NUMBER)
    7 FORMAT(20XF10.5,F10.7,F10.8,I10)
      READINPUTTAPE2,9,(PVAR(I),I=1,NVAR)
    9 FORMAT(F9.1,3(F11.1),3(F10.1))
      READINPUTTAPE2,11,(PCONST(I),I=1,NCONST)
   11 FORMAT(F9.1,3(F11.1),3(F10.1))
      READINPUTTAPE2,13,(CCOEFS(I),I=1,NCONST)
   13 FORMAT(F9.6,3(F11.6),3(F10.6))
   14 CALLDP(20000)
      DO17I=1,7
      DO17J=1,15
   17 A(I,J)=0.0
      NVP1=NVAR+1
      DO33I=1,NUMBER
      TTWO=T(I)+DT(I)/2.0
      TONE=T(I)-DT(I)/2.0
      DO23J=1,NVAR
      P=PVAR(J)+1.0
   23 CPFN(J)=(PWR(TTWO,P)-PWR(TONE,P))/(P*(TTWO-TONE))
      SUMC=0.0
      DO27J=1,NCONST
      P=PCONST(J)+1.0
   27 SUMC=SUMC+CCOEFS(J)*(PWR(TTWO,P)-PWR(TONE,P))/(P*(TTWO-TONE))
      CPFN(NVP1)=CP(I)-SUMC
      CP(I)=CPFN(NVP1)
      LVECPM=1
      DO33J=1,NVAR
      DO33K=1,NVP1
   33 A(J,K)=A(J,K)+CPFN(J)*CPFN(K)
      NVPNV=NVP1+NVAR
      DO39I=1,NVAR
      NDUMMY=NVP1+I
      A(I,NDUMMY)=1.0
      DO39J=1,NVPNV
   39 B(I,J)=A(I,J)
      NVM1=NVAR-1
```

```
 41 DO49K=1,NVM1
    L=K+1
    DO49I=L,NVAR
    IF(B(I,K))45,49,45
 45 QUOT=B(K,K)/B(I,K)
    DO48J=L,NVPNV
    B(I,J)=B(I,J)*QUOT-B(K,J)
 48 CONTINUE
 49 CONTINUE
    J=NVAR
    VCOEFS(J)=B(J,J+1)/B(J,J)
 51 IF(J-1)986,58,52
 52 SIGMA=0.0
    DO54I=J,NVAR
 54 SIGMA=SIGMA+VCOEFS(I)*B(J-1,I)
    VCOEFS(J-1)=(B(J-1,NVP1)-SIGMA)/B(J-1,J-1)
    J=J-1
    GOTO51
 58 DO69I=1,NUMBER
    TTWO=T(I)+DT(I)/2.0
    TONE=T(I)-DT(I)/2.0
    SUMV=0.0
    DO64J=1,NVAR
    P=PVAR(J)+1.0
 64 SUMV=SUMV+VCOEFS(J)*(PWR(TTWO,P)-PWR(TONE,P))/(P*(TTWO-TONE))
 69 DEV(I)=SUMV-CP(I)
    GOTO(71,100),LVECPM
 71 OMIT(1)=1.0
    OMIT(2)=1.0
    OMIT(NUMBER-1)=1.0
    OMIT(NUMBER)=1.0
    N=0
    DO93I=1,NUMBER
112 TM1=0.0
    TM2=0.0
    TP1=10.0
    TP2=10.0
    DO138J=1,NUMBER
120 IF (T(I)-T(J)) 121,138,130
121 IF(T(J)-TP2)122,122,138
122 IF(T(J)-TP1)125,125,123
123 TP2=T(J)
    NP2=J
    GO TO 138
125 TP2=TP1
    NP2=NP1
    TP1=T(J)
    NP1=J
    GOTO138
130 IF(T(J)-TM2)138,131,131
131 IF(T(J)-TM1)132,132,134
132 TM2=T(J)
    NM2=J
    GO TO 138
```

```
134 TM2=TM1
    NM2=NM1
    TM1=T(J)
    NM1=J
138 CONTINUE
    IF(TM2)996,81,77
 77 IF(TP2-10.0)78,81,995
 78 AVDEV=(DEV(NM2)*DEV(NM2)+DEV(NM1)*DEV(NM1)+DEV(NP1)*DEV(NP1)
   1+DEV(NP2)*DEV(NP2))/4.0
    ABSMD=DEV(I)*DEV(I)
    IF(ABSMD-9.0*AVDEV)81,83,83
 81 OMIT(I)=1.0
    GOTO93
 83 OMIT(I)=0.0
    N=1
    TTWO=T(I)+DT(I)/2.0
    TONE=T(I)-DT(I)/2.0
    DO88J=1,NVAR
    P=PVAR(J)+1.0
 88 CPFN(J)=(PWR(TTWO,P)-PWR(TONE,P))/(P*(TTWO-TONE))
    CPFN(NVP1)=CP(I)
    DO92J=1,NVAR
    DO92K=1,NVP1
 92 A(J,K)=A(J,K)-CPFN(J)*CPFN(K)
 93 CONTINUE
    IF(N)985,100,95
 95 LVECPM=2
    DO98I=1,NVAR
    DO98J=1,NVPNV
 98 B(I,J)=A(I,J)
    GOTO41
100 NVP2=NVAR+2
    DO109J=NVP2,NVPNV
    K=NVAR
    COEFW(K,J)=B(K,J)/B(K,K)
102 IF(K+NVP1-J)984,109,103
103 SIGMA=0.0
    DO105I=K,NVAR
105 SIGMA=SIGMA+COEFW(I,J)*B(K-1,I)
    COEFW(K-1,J)=(B(K-1,J)-SIGMA)/B(K-1,K-1)
    K=K-1
    GOTO102
109 CONTINUE
    SUMNO=0.0
    SUMV2=0.0
    DO144I=1,NUMBER
    IF(OMIT(I))983,144,142
142 SUMV2=SUMV2+DEV(I)*DEV(I)
    SUMNO=SUMNO+1.0
144 CONTINUE
    FNNO=NVAR
    SUMNO=SUMNO-FNNO
```

```
      DO149I=1,NVAR
      NDUMMY=I+NVP1
  149 STD(I)=SQRTF(SUMV2*ABSF(COEFW(I,NDUMMY))/SUMNO)
      CALLLVE
      IF(SENSESWITCH6)151,150
  150 PRINT152,(NAME(I),I=1,12)
      PRINT154
      PRINT156
      PRINT158
      PRINT160,(PVAR(I),I=1,NVAR)
      PRINT162
      PRINT164,(VCOEFS(I),I=1,NVAR)
      PRINT166
      PRINT168,(STD(I),I=1,NVAR)
      PRINT170
      PRINT172,(PCONST(I),I=1,NCONST)
      PRINT174
      PRINT176,(CCOEFS(I),I=1,NCONST)
      PRINT178
      GOTO179
  151 WRITEOUTPUTTAPE6,152,(NAME(I),I=1,12)
  152 FORMAT(1H112A6)
      WRITEOUTPUTTAPE6,154
  154 FORMAT(/31H CORRECTED SPECIFIC HEAT OUTPUT)
      WRITEOUTPUTTAPE6,156
  156 FORMAT(//30X21HVARIABLE COEFFICIENTS)
      WRITEOUTPUTTAPE6,158
  158 FORMAT(/35X11HPOWERS OF T)
      WRITEOUTPUTTAPE6,160,(PVAR(I),I=1,NVAR)
  160 FORMAT(/1H 7F15.8)
      WRITEOUTPUTTAPE6,162
  162 FORMAT(/34X12HCOEFFICIENTS)
      WRITEOUTPUTTAPE6,164,(VCOEFS(I),I=1,NVAR)
  164 FORMAT(/1H 7F15.8)
      WRITEOUTPUTTAPE6,166
  166 FORMAT(/31X19HSTANDARD DEVIATIONS)
      WRITEOUTPUTTAPE6,168,(STD(I),I=1,NVAR)
  168 FORMAT(/1H 7F15.8)
      WRITEOUTPUTTAPE6,170
  170 FORMAT(//30X21HCONSTANT COEFFICIENTS,//35X11HPOWERS OF T)
      WRITEOUTPUTTAPE6,172,(PCONST(I),I=1,NCONST)
  172 FORMAT(/1H 7F15.8)
      WRITEOUTPUTTAPE6,174
  174 FORMAT(/34X12HCOEFFICIENTS)
      WRITEOUTPUTTAPE6,176,(CCOEFS(I),I=1,NCONST)
  176 FORMAT(/1H 7F15.8)
      WRITEOUTPUTTAPE6,178
  178 FORMAT(//51H   C (MJ)        T (DEG K)      DELTA T        C(F)-C(E)
     1/120X)
  179 ARG(1)=0.0
      ARG(2)=0.0
      ARG(3)=0.0
      DO204I=1,NUMBER
      CALLDP(20000)
```

```
      SUMV=0.0
      DO186J=1,NVAR
  186 SUMV=SUMV+VCOEFS(J)*PWR(T(I),PVAR(J))
      SUMC=0.0
      DO189J=1,NCONST
  189 SUMC=SUMC+CCOEFS(J)*PWR(T(I),PCONST(J))
      CP(I)=SUMV+SUMC-DEV(I)
      CALLLVE
      IF(SENSESWITCH6)192,190
  190 IF(OMIT(I))982,188,187
  187 PRINT194,CP(I),T(I),DT(I),DEV(I),NCODE(I)
      GOTO198
  188 PRINT197,CP(I),T(I),DT(I),DEV(I),NCODE(I)
      GOTO198
  192 IF(OMIT(I))982,196,193
  193 WRITEOUTPUTTAPE6,194,CP(I),T(I),DT(I),DEV(I),NCODE(I)
  194 FORMAT(1H F10.5,F13.8,F13.8,F14.7,I12)
      GOTO198
  196 WRITEOUTPUTTAPE6,197,CP(I),T(I),DT(I),DEV(I),NCODE(I)
  197 FORMAT(1H F10.5,F13.8,F13.8,F14.7,I12,9H      OMIT)
  198 IF(ABSF(CP(I))-ARG(1))200,200,199
  199 ARG(1)=ABSF(CP(I))
  200 IF(ABSF(T(I))-ARG(2))202,202,201
  201 ARG(2)=ABSF(T(I))
  202 IF(ABSF(DEV(I))-ARG(3))204,204,203
  203 ARG(3)=ABSF(DEV(I))
  204 CONTINUE
      DO215I=1,3
      SCALE(I)=1.0
      IF(ARG(I)-1.0)210,211,212
  208 ARG(I)=ARG(I)*10.0
      SCALE(I)=SCALE(I)*10.0
  210 IF(ARG(I)-0.1)208,215,215
  211 SCALE(I)=SCALE(I)/10.0
  212 ARG(I)=ARG(I)/10.0
      SCALE(I)=SCALE(I)/10.0
      IF(ARG(I)-1.0)215,212,212
  215 CONTINUE
      DO222I=1,NUMBER
      PP1=CP(I)*SCALE(1)
      PP2=T(I)*SCALE(2)
      PP3=DEV(I)*SCALE(3)
      IF(SENSESWITCH6)220,219
  219 PUNCH225,PP2,PP1,PP3,OMIT(I),NCODE(I)
  221 FORMAT(1HQF10.7,F10.7,F10.7,10XF10.1,I10)
      GOTO222
  220 WRITEOUTPUTTAPE6,221,PP2,PP1,PP3,OMIT(I),NCODE(I)
  225 FORMAT(F10.7,F10.7,F10.7,10X,F10.1,I10)
  222 CONTINUE
      IF(SENSESWITCH6)223,224
  223 ENDFILE6
  224 STOP77777
```

```
996 STOP64
995 STOP65
986 STOP16
985 STOP17
984 STOP20
983 STOP21
982 STOP22
    END(0,1,0,0,1)
```

```
      FUNCTIONPWR(T,P)
      GOTO13
    1 IF(P+5.0)22,24,2
    2 IF(P+4.5)22,26,22
    3 IF(P+4.0)1,28,5
    4 IF(P+3.5)22,30,22
    5 IF(P+3.0)4,32,6
    6 IF(P+2.5)22,34,22
    7 IF(P+2.0)3,36,10
    8 IF(P+1.5)22,38,22
    9 IF(P+1.0)8,40,22
   10 IF(P+0.5)9,42,11
   11 IF(P)22,44,12
   12 IF(P-0.5)22,46,22
   13 IF(P-1.0)7,48,17
   14 IF(P-1.5)22,50,15
   15 IF(P-2.0)22,52,16
   16 IF(P-2.5)22,54,22
   17 IF(P-3.0)14,56,21
   18 IF(P-3.5)22,58,22
   19 IF(P-4.0)18,60,20
   20 IF(P-4.5)22,62,22
   21 IF(P-5.0)19,64,22
   22 PWR=T**P
      GOTO65
   24 PWR=1.0/(T*T*T*T*T)
      GOTO65
   26 PWR=1.0/(T*T*T*T*SQRTF(T))
      GOTO65
   28 PWR=1.0/(T*T*T*T)
      GOTO65
   30 PWR=1.0/(T*T*T*SQRTF(T))
      GOTO65
   32 PWR=1.0/(T*T*T)
      GOTO65
   34 PWR=1.0/(T*T*SQRTF(T))
      GOTO65
   36 PWR=1.0/(T*T)
      GOTO65
   38 PWR=1.0/(T*SQRTF(T))
      GOTO65
   40 PWR=1.0/T
      GOTO65
   42 PWR=1.0/SQRTF(T)
      GOTO65
   44 PWR=1.0
      GOTO65
   46 PWR=SQRTF(T)
      GOTO65
   48 PWR=T
      GOTO65
   50 PWR=T*SQRTF(T)
```

```
      GOTO65
   52 PWR=T*T
      GOTO65
   54 PWR=T*T*SQRTF(T)
      GOTO65
   56 PWR=T*T*T
      GOTO65
   58 PWR=T*T*T*SQRTF(T)
      GOTO65
   60 PWR=T*T*T*T
      GOTO65
   62 PWR=T*T*T*T*SQRTF(T)
      GOTO65
   64 PWR=T*T*T*T*T
   65 RETURN
      END(0,1,0,0,1)
```

X